

DEP SPECIFICATION

NON-METALLIC MATERIALS – SELECTION AND APPLICATION

DEP 30.10.02.13-Gen.

February 2012

DESIGN AND ENGINEERING PRACTICE



© 2012 Shell Group of companies
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of the copyright owner or Shell Global Solutions International BV.

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of Shell Global Solutions International B.V. (Shell GSI) and, in some cases, of other Shell Companies.

These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

The objective is to set the standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual Operating Units to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs, they shall be solely responsible for such use, including the quality of their work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will typically expect them to follow those design and engineering practices that will achieve at least the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal.

The right to obtain and to use DEPs is restricted, and is granted by Shell GSI (and in some cases by other Shell Companies) under a Service Agreement or a License Agreement. This right is granted primarily to Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or another Shell Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorised to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Company, or companies affiliated to these companies, that may issue DEPs or advise or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell Group of companies. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in Shell GSI.

TABLE OF CONTENTS

1.	INTRODUCTION	5
1.1	SCOPE.....	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	5
1.4	CROSS-REFERENCES	10
1.5	SUMMARY OF MAIN CHANGES.....	10
1.6	COMMENTS ON THIS DEP	10
1.7	DUAL UNITS.....	10
1.8	SOURCES	10
2.	GENERAL.....	11
2.1	CATEGORIES OF NON METALLICS	11
2.2	MATERIALS SELECTION PROCESS	11
3.	THERMOPLASTIC MATERIALS	12
3.1	GENERAL	12
3.2	PLASTICISED POLYVINYL CHLORIDE (PVC).....	12
3.3	UNPLASTICIZED POLYVINYL CHLORIDE (PVC-U)	12
3.4	CHLORINATED POLYVINYL CHLORIDE (PVC-C).....	12
3.5	POLYETHYLENE (PE)	13
3.6	POLYAMIDE (PA).....	15
3.7	POLYPROPYLENE (PP)	16
3.8	FLUORO POLYMERS (PTFE, PCTFE, PFA, FEP, PVDF).....	18
3.9	POLYPHENYLENE SULPHIDE (PPS).....	20
3.10	POLYETHERETHERKETONE (PEEK)	21
4.	THERMOSET MATERIALS AND COMPOSITES	22
4.1	GENERAL	22
4.2	TEMPERATURE LIMITATIONS	22
4.3	CHEMICAL RESISTANCE OF RESINS.....	22
5.	ELASTOMER MATERIALS	24
5.1	GENERAL	24
5.2	NATURAL RUBBER (NR).....	24
5.3	STYRENE BUTADIENE RUBBER (SBR)	24
5.4	POLYCHLOROPRENE RUBBER (CR).....	25
5.5	BUTYL RUBBER (IIR)	25
5.6	CHLOROSULPHONATED POLYETHYLENE (CSM)	25
5.7	NITRILE BUTADIENE RUBBER (NBR)	26
5.8	HYDROGENATED NITRILE BUTADIENE RUBBER (HNBR)	26
5.9	ETHYLENE PROPYLENE DIENE-M RUBBER (EPDM).....	26
5.10	FLUOROELASTOMERS (FKM)	27
5.11	PERFLUORO ELASTOMER (FFKM)	28
5.12	POLYTETRAFLUOROETHYLENE/PROPYLENE (FEPM).....	29
5.13	FLUORO-SILICONE RUBBERS (VMQ, PMQ, FMQ)	29
5.14	POLYURETHANE RUBBERS (AU, EU).....	29
5.15	RAPID GAS DECOMPRESSION OF ELASTOMER SEAL MATERIALS	29
5.16	ELASTOMER SELECTION – UPSTREAM SERVICES.....	29
5.17	ELASTOMER STORAGE	32
5.18	QUALIFICATION OF ELASTOMERS.....	32
6.	CERAMIC MATERIALS	33
6.1	GENERAL	33
6.2	NON-OXIDE CERAMICS.....	33
6.3	OXIDE CERAMICS	33
7.	INSULATION MATERIALS	33
8.	REFERENCES	37
9.	SOURCES	39

APPENDICES

APPENDIX 1 MATERIALS.....40

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the selection and application of non-metallic materials. The following categories of non-metallic materials are covered:

- Thermoplastic materials;
- Thermoset materials;
- Fibre reinforced materials;
- Composite materials;
- Elastomeric materials;
- Ceramic materials;
- Insulation materials.

This DEP, and the companion Informative document, contain a compilation of screened internal and external references and provide materials data for non-metallic materials in contact with media related to specific (petro)chemical and oil and gas services. The DEP Specification is streamlined for project use and includes guidance that may be used by the Contractor.

It should be noted that this DEP provides requirements and guidelines to be applied on projects, but is not a materials specification.

More detailed guidance on materials selection for non-metallic materials is provided to the engineering community of the Principal in Section 2 of the companion Informative document.

This is a major revision of the DEP of the same number dated April 2003.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
Ceramic	Crystalline or partly crystalline structure produced from essentially inorganic, non-metallic substances and formed either from a molten mass solidified on cooling, or simultaneously or subsequently formed by the action of heat (ASTM C 242).
Coating	A liquid or mastic compound which, after applying as a thin layer, converts into an adherent, solid and protective, decorative or functional film (ASTM D 16).
Elastomer	A polymer material with similar properties to rubber (ASTM D 1566). NOTE: This term should not be used as a synonym for rubber.
Insulation Material	A foamed or syntactic variation of a thermoplastic material, providing improved thermal resistance over the base thermoplastic polymer, fibrous inorganic material, cellular glass, amorphous silica and refractory.
Paint	A pigmented coating (ASTM D 16).
Refractory	An inorganic material with chemical and physical properties applicable for structures and system components exposed to environments above 538°C (1000°F) (ASTM C 71)
Rubber	A material capable of quickly and forcibly recovering from all deformations (ASTM D 1566).
Thermoplastic	A plastic that repeatedly will soften by heating and harden by cooling within a temperature range characteristic for the plastic. In the softened state, it can be shaped by flow into articles, e.g., by moulding/extrusion (ASTM D 883).
Thermoset	A plastic which is substantially infusible and insoluble after curing by heat or other means (ASTM D 883).

1.3.3 Abbreviations

Abbreviations are commonly used to describe non-metallic materials. A number of abbreviations standardised in various codes, e.g., ASTM D 1418 and ASTM D 1600, ISO 1043 and ISO 1629, are listed below.

Term	Definition
ABR	Acrylate Butadiene Rubber
ABS	Acrylonitrile Butadiene Styrene
ANSI	American National Standards Institute
API	American Petroleum Institute
ASA	Acrylonitrile Styrene Acrylate
ASTM	American Society for Testing and Materials
BR	Butadiene Rubber

Term	Definition
BS	Butadiene Styrene
CA	Cellulose Acetate
CAB	Cellulose Acetate Butyrate
CAP	Cellulose Acetate Propionate
CFM	Polychlorotrifluoroethylene
CM	Chloropolyethylene
CP	Cellulosepropionate
CPE	Chlorinated Polyethylene
CPVC	Chlorinated Polyvinylchloride
CR	Chloroprene Rubber
CSM	Chlorosulphonated Polyethylene
DAP	Diallyl Phthalate
ECTFE	Ethylenechlorotrifluoroethylene
EPR	Ethylene Propylene Rubber
EPS	Expanded Polystyrene
EP	Exploration and Production
EPDM	Ethylene Propylene Rubber
ESC	Environmental Stress Cracking
ETFE	Ethylene Tetrafluoroethylene
EVA	Ethylene Vinylacetate
EVAC	Ethylene Vinylacetate
EVAL	Ethylene Vinylalcohol
FEP	Fluorinated Ethylene Propylene
FKM	Fluorocarbon Co-polymer
FFKM	Perfluoro Elastomer
FMK	Fluor-Silicone Rubber
FMQ	Fluor-Silicone Rubbers
FRP	Fibre Reinforced Plastic
GR-A	Apolybutadiene Acrylonitrile Rubber
GR-I	Butyl Rubber, Polyisobutylene Isoprene Rubber
GR-N	Nitrile Rubber, Nitrile Butadiene Rubber, Polybutadiene Acrylonitrile Rubber
GR-S	Styrene Butadiene Rubber, Polybutadiene Styrene Rubber
GRE	Glass Reinforced Epoxy
GRP	Glass Reinforced Plastic
GRUP	Glass Reinforced Unsaturated Polyester
GRVE	Glass Reinforced Vinyl Ester
HNBR	Hydrogenated Nitrile Butadiene Rubber

Term	Definition
IIR	Butyl Rubber
IM	Polyisobutene Rubber
IR	Isoprene Rubber
ISSO	International Standards Organisation
MDI	Diphenylmethane Diisocyanate
MF	Melamine Formaldehyde
NBR	Nitrile Butadiene Rubber
NR	Natural Rubber
OP	Oil Products
PA	Polyamide (Nylon)
PAI	Polyaramide Imide
PAN	Polyacrylonitrile
PB	Polybutylene
PBTP	Polybutylene Terephthalate
PC	Polycarbonate
PCTFE	Polychlorotrifluoroethylene
PEEK	Polyetheretherketone
PE	Polyethylene
PE-C	Polyethylene, chlorinated; preferred term for CPE
PE-HD	Polyethylene high density; preferred term for HDPE
PE-LD	Polyethylene, low density; preferred term for LDPE
PE-LLD	Polyethylene, linear low density; preferred term for LLDPE
PE-MD	Polyethylene, medium density; preferred term for MDPE
PE-UHMW	Polyethylene, ultra high molecular weight; preferred term for UHMWPE
PE-VLD	Polyethylene, very low density; preferred term for VLDPE
XLPE or PEX	Cross-linked Polyethylene consisting of long polymer chains in a 3-dimensional structure
PEI	Polyetherimide
PES	Polyethersulfone
PETP	Polyethylene Terephthalate
PEX	Cross-linked Polyethylene
PF	Phenol Formaldehyde
PFA	Perfluoroalkoxy Copolymer
PFEP	Fluorinated Ethylene Propylene
PI	Polyimide
PIB	Polyisobutylene
PiP	Pipe-in-Pipe
PIR	Poly-isocyanurate Rubber

Term	Definition
PMMA	Polymethyl Methacrylate
PMQ	Fluor-Silicone Rubbers
POM	Polyoxymethylene, Polyformaldehyde
PP	Polypropylene
PPO	Polyphenylene Oxide
PPS	Polyphenylene Sulphide
PS	Polystyrene
PSU	Polysulfone
PTFE	Polytetrafluoridethylene
PUF	Polyurethane (foam)
PUR	Polyurethane
PVAC	Polyvinyl Acetate
PVAL	Polyvinyl Alcohol
PVC	Plasticised Polyvinylchloride
PVC-C	Chlorinated Polyvinylchloride
PVC-U	Unplasticised Polyvinylchloride
PVCC	Chlorinated Polyvinyl Chloride
PVDC	Polyvinylidene Chloride
PVDF	Polyvinylidenefluoride
PVF	Polyvinyl Fluoride
RGD	Rapid Gas Decompression
SAN	Styrene Acrylonitrile
SB	Styrene Butadiene
SBR	Styrene Butadiene Rubber
SI	Silicone
SIC	Silicon Carbide
TFE	Polytetrafluoroethylene
TPE	Thermoplastic Elastomers
TPU	Thermoplastic Polyurethane
(A)U, (E)U	Polyurethane AU (Polyester), EU (Polyether)
UF	Ureum Formaldehyde
UP	Unsaturated Polyester
UV	Ultra Violet Light
VAC	Vinylacetate
VC	Vinylchloride
VMQ	Fluor-Silicone Rubbers
w/w	Type of percentage solution (weight/weight)
XPS	Extruded Polystyrene

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (8).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a major revision of the DEP of the same number dated April 2003, and the changes are too numerous to list here.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

1.8 SOURCES

The sources used for data shown in this DEP are listed in (9) and are indicated in the document by the use of square brackets [].

2. GENERAL

2.1 CATEGORIES OF NON METALLICS

The following categories of non-metallic materials are covered by this DEP:

- a) Thermoplastic materials;
- b) Thermoset materials;
- c) Fibre reinforced materials;
- d) Composite materials;
- e) Elastomeric materials;
- f) Ceramic materials;
- g) Insulation materials.

2.2 MATERIALS SELECTION PROCESS

The materials selection process shall ensure that the material is compatible with the service fluids to which it is exposed over the full design temperature range so that the mechanical, physical and chemical properties of the component/system satisfy the design requirements throughout the intended lifetime.

For a number of polymers and applications, **generic** allowable operating conditions are provided in this DEP. The application specific DEPs listed in Table 2.1 provide more in depth guidance on materials selection, acceptance criteria, component design and materials qualification requirements. The application specific DEPs shall be governing.

Table 2.1 Application specific DEPs

DEP 30.48.60.10-Gen.	Rubber Lined Process Equipment
DEP 31.22.30.14-Gen.	Glass-Fibre Reinforced Plastic Vessels
DEP 31.40.10.19-Gen.	Glass Fire Reinforced Plastic Pipeline and Piping Systems
DEP 31.40.10.20-Gen.	Spoolable Fibre-Reinforced Plastic Pipes
DEP 31.40.20.39-Gen.	High Density Polyethylene Pipelines and Piping Systems for Oilfield Applications
DEP 31.40.30.31-Gen.	External Polyethylene and Polypropylene Coating for Line Pipe
DEP 31.40.30.34-Gen.	Thermoplastic Lined Pipelines
DEP 64.24.32.30-Gen.	Insulating and Dense Refractory Concrete Linings
DEP 30.46.00.31-Gen.	Thermal Insulation
DEP 30.48.00.31-Gen.	Protective Coatings for Onshore Facilities
DEP 30.48.60.13-Gen.	Design and Installation of Chemical-Resistant Brick Lining for Process Equipment
DEP 30.48.60.12-Gen.	Design and Installation of Chemical-Resistant Linings for Concrete Structures

3. THERMOPLASTIC MATERIALS

3.1 GENERAL

The most commonly applied thermoplastics (or those having the greatest potential for use) in EP, Refining and Chemicals applications are discussed in more detail in the following sections. They are:

- a) Plasticised Polyvinyl Chloride (PVC);
- b) Unplasticised PVC (PVC-U);
- c) Polyethylene (PE);
- d) Polyamide (PA);
- e) Polypropylene (PP);
- f) Fluor Polymers (PTFE, PCTFE, PFA, FEP, PVDF);
- g) Polyphenylene Sulphide (PPS);
- h) Cross-linked Polyethylene (PEX);
- i) Polyetheretherketone (PEEK).

The application of thermoplastic liners in carbon steel pipelines and flow lines shall be in accordance with DEP 31.40.30.34-Gen.

The application of polyethylene (PE) and polypropylene (PP) thermoplastic material for external coating of line pipe shall be in accordance with DEP 31.40.30.31-Gen.

The application of thermoplastic material in flexible pipes is specified in ISO 13628-2.

NOTE: The minimum/maximum service temperatures provided in the sections below may be limited for pressure pipe. Commentary on this topic is included in the DEP Informative.

3.2 PLASTICISED POLYVINYL CHLORIDE (PVC)

PVC-U and PVC-C have replaced plasticised PVC.

3.3 UNPLASTICIZED POLYVINYL CHLORIDE (PVC-U)

PVC-U is resistant to inorganic chemicals and several organic chemicals. It is not resistant against aromatic and chlorinated hydrocarbons. Resistance to sodium hypochlorite, sodium hydroxide and dry chlorine gas has developed its use within the chemical (chlorine) industry.

Generally, PVC-U is used as chemical resistant lining in GRP storage vessels, and GRP pipe and fittings.

The maximum service temperature for PVC-U is 60°C (140°F), and the lower limit is 0°C (32°F).

3.4 CHLORINATED POLYVINYL CHLORIDE (PVC-C)

PVC-C is a chlorinated PVC grade which has, for certain services, a better chemical resistance compared to PVC-U. Maximum service temperature is in accordance with Table 3.4 for the services indicated.

**Table 3.4 Maximum service temperature (ISO 10358)
of PVC-U and PVC-C**

	PVC-U	PVC-C
Sulphuric acid, 50 % to 90 %	20°C (68°F)	60°C (140°F)
Sodium hydroxide 10 % - 60 %	60°C (140°F)	60°C (140°F)
Sodium hypochlorite (12.5 % Cl)	60°C (140°F)	100°C (140°F)

3.5 POLYETHYLENE (PE)

The maximum service temperature for PE is 60°C (140°F), while the lower temperature limit is -30°C (-22°F).

The material has limited resistance against weathering, and sunlight/UV exposure, and therefore requires additional UV protection, when used outdoor.

NOTE: For liner applications and Reinforced Thermoplastic Pipe (RTP), the maximum operating temperature of HDPE may be extended to 65°C (150°F).

Polyethylenes have a limited suitability when aromatics are present in the fluids.

The maximum allowable temperatures for polyethylenes is in accordance with Table 3.5a and Table 3.5b. For services not listed in the table, refer to external sources.

**Table 3.5a Maximum service temperature (ISO 10358 [1])
of PE grades in °C (°F)**

Fluid composition	Maximum service temperature for PE-HD In °C (°F)
Crude oil/gas applications	See Table 3.5b
Gas and condensate	50(122)
Dry gas	60 (140)
Water	60 (140)
Sulphuric acid up to conc. < 80 % w/w	40 (104) to 60(140) ^a
Nitric acid up to conc. of 25 % w/w	60 (140)
Hydrochloric acid, up to 40 % w/w	60 (140)
Sodium hydroxide, up to 70 % w/w	60 (140)
Phosphoric acid, up to 50% w/w	60 (140)
NOTES: a Source: [2, 3]: 40°C (104°F): suitable, 60°C (140°F): limited chemical compatibility	

Table 3.5b General performance of polyethylenes
(Source ISO 23936-1 [4])

Medium/Media	Environmental condition(s)	
	Maximum service temperature ^d °C (°F)	Description
H ₂ S	0 to 60 (32 to 140) ^a	No influence of H ₂ S on stability of PE in typical temperature range of oil and gas transport.
CO ₂	0 to 60 (32 to 140) ^a	As for H ₂ S.
HC/crude aliphatics, aliphatic oils	0 to 60 (32 to 140) ^{a,b}	Cross-linked PE (PE-X, XPE) exhibit better performance.
HC/crude aromatics, aromatic oils	0 to 20 (32 to 68) ^c	Only cross-linked PE may be acceptable in special cases. Problem: swelling and permeation strongly influence the physical properties.
HC/crude naphthenics, HC/crude cycloaliphatics, cycloaliphatic oils	0 to 20 (32 to 68) ^c	As for aromatics: dissolution at higher temperatures (e.g. > 100°C [212°F]).
Brine	0 to 60 (32 to 140) ^a	As for H ₂ S
Acids, Bases (caustic service)	0 to 60 (32 to 140) ^a	No effect from inorganic non-oxidizing acids or bases. Formic and acetic acid have no effect up to 60% w/w concentration.
Surface-active compounds (inhibitors, emulsifiers, demulsifiers)	0 to 60 (32 to 140) ^c	Stress corrosion cracking has to be considered and tested accordingly. Cross-linked PE types are more stable.
Sulfur Solvents:		
Amines	0 to 60 (32 to 140) ^a	Cross-linked types are more stable.
Spindle oil, diesel	0 to 60 (32 to 140) ^c	Effects like the corresponding crudes.
Disulfides	0 to 60 (32 to 140) ^c	
NOTE: Cross-linked PE (PE-X) generally improves the resistance to chemical degradation.		
a Proven applicability. b Limited applicability. c Testing required. d Temperature limitations relate to HDPE.		

3.6 POLYAMIDE (PA)

Polyamide (PA) has good resistance to hydrocarbons but limited resistance to water at elevated temperatures. The maximum service temperature for PA is 80°C (176°F), while the lower temperature limit is minus 30°C (-22°F).

Table 3.6a provides general performance of polyamides under typical oil and gas production conditions

Table 3.6a General performance of PA-11 and PA-12
(Source ISO 23936-1 [4])

Medium/Media	Environmental condition(s)	
	Temperature °C (°F)	Description
H ₂ S, CO ₂	0 to 70 (32 to 158) ^a	No influence of H ₂ S on stability of PA-11 and PA-12 in typical temperature range of oil and gas transport 0°C to 90°C (32°F to 194°F). If presence of water cannot be excluded in all cases, PA-11 and PA-12 (which undergo hydrolysis at temperatures above 80°C [176°F]) cannot be recommended for higher temperatures.
HC/crude aliphatics, aliphatic oils	0 to 70 (32 to 158) ^a	—
HC/crude aromatics, aromatics oils	0 to 70 (32 to 158) ^c	—
HC/crude naphthenics, HC/crude cycloaliphatics, cycloaliphatics oils	0 to 70 (32 to 158) ^c	—
Brine	0 to 70 (32 to 158) ^a	At higher temperatures, hydrolysis occurs.
Acids	^b	Acid degradation.
Bases	^b	Degradation by hydrolysis.
Surface-active compounds (inhibitors, emulsifiers, demulsifiers)	0 to 70 (32 to 158) ^c	—
Sulfur solvents:		
amines	^b	Loss of mechanical properties.
spindle oil, diesel	0 to 70 (32 to 158) ^a	—
disulfides	0 to 70 (32 to 158) ^c	—
a Proven applicability. b Not recommended. c Testing required.		

Effect of production chemicals on PA performance

API 17TR2 provides the following additional limitations due to ageing effects in combination with production chemicals (Table 3.6b):

**Table 3.6.b Effect of production chemicals on PA performance
(Source API 17TR2 report [5])**

Production Chemical	Chemical Nature	Continuous Injection	Effect of Neat Chemical
Aromatic solvents	Benzene, toluene, xylene	No effect	Swelling above 40°C (104°F). Minimize exposure
Calcium carbonate scale dissolver	Strong inorganic acids, Na EDTA and alternatives	Not used in dilute form	Strong inorganic acids should not be used in PA-11 pipe/liners
Barium sulphate scale dissolver	Strong alkalis	Not used in dilute form	Strong alkalis above pH = 10 should not be used in PA-11 pipe.
Wax and asphaltene dissolvers	Aromatic solvents, e.g. xylene, or terpene based solvents, e.g. based on leminene	No effect	Aromatic solvents can cause swelling above 40°C (104°F). Minimise exposure.
Hydrate inhibitor	Neat alcohol, normally methanol or glycol, but may be ethanol.	See note ^a below	See note ^a below
NaOH	Hydrate inhibition	Not used in dilute form	Strong alkalis above pH = 10 should not be used in PA-11 pipe.
Corrosion inhibitor	Ethoxylated and quaternary amines in aqueous glycols or alcohols. pH in range 4 – 8	No effect	PA-11 pressure sheath not normally in contact with neat chemical, but will be aggressive and should be avoided.

NOTE: a Pure, liquid methanol diffuses easily and quickly through PA-11 and very effectively extracts plasticiser and swells the material. In addition, industry grades methanol often contains traces of oxygen. This oxygen leads to degradation of the PA-11.

Effect of pH

pH shall be taken into account. For details, refer to the API 17TR2 report.

3.7 POLYPROPYLENE (PP)

The maximum service temperature for oil and gas service is 80°C (176°F), depending on the service conditions and PP grade.

The minimum allowable service temperature depends on the PP grade. For homopolymer grades, the minimum allowable temperature is about +4°C (39°F), for co-polymer types the minimum allowable service temperature is -20°C (-4°F).

The maximum service temperature is provided in Table 3.7a and Table 3.7b.